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DEVELOPMENT OF ELECTROMAGNETIC ENGINE FOR FUTURE TRANSPORT APPLICATIONS

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ABSTRACT

Trade Has Been Seeing To End Its Dependency On Oil. Moreover Currently The Need For Fuel Has Amplified And In The Near Future, Scarcity Of Fossil Fuels Is Being Expected Due To Their Endlessly Growing Consumption. The Present Work Focusses On The Development Of Electromagnetic Engines As An Alternate For The Existing Fuel Combustion Engines. Various Probabilities Were Carried Out In Developing An Electromagnetic Engine And The Magnetic Flux Produced By The Electromagnet To Give Required Force To The Piston And Power Output Produced By Engine Were Calculated.

KEYWORDS: Electromagnetic Engine, Magnetic Flux & Existing Fuel

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Original Article

INTRODUCTION

Since ages the human mankind has invented many new technologies which will help to reduce his effort for his daily needs. One such kind of invention is an "engine". The internal combustion engine is an engine in which the combustion of a fuel occurs with an oxidizer in a combustion chamber that is an integral part of the engine. The main problem with the conventional IC engine is that they need fuel for combustion and when these fuels are burnt there is liberation of large amount of pollutants. Another concern is that people tend to use gasoline propelled vehicles even for short distance travel, although electric vehicles are available in the market for some time but are not that very popular because of high cost and less durability. The growing demand for fuel and the depletion of fuel reserves have made it the need of the hour to use alternate engine system [1].

A need for unique form engine was required, to increase the travel at very cost effective way. Therefore there was urgent requirement to come up with a substitute form of an engine which is completely eco-friendly and easy to maintain. The electromagnetic engine can substitute as an alternative engine. It works completely on battery current, thus controlling the pollution to very large extent. It can be considered as a completely green technology [2,3].

Atul Kumar et.al have described that the electromagnetic engine uses electric power to run which is cleaner and cheaper than fossil fuels. The paper makes use of solenoids which act as magnet when electricity is supplied to them [4].

Vishal AbasahebMasilet, al have described about the working principle of an electromagnetic engine which is different from motor. An engine was constructed using electromagnet and permanent magnet itself asa piston of the engine [5].

Shirsendu Das has described the calculation of power considering the weight of the piston in both the upward and downward movement of the piston. The paper makes use of solenoids which act as magnet when electricity is supplied to them [6].

Development of an electromagnetic engine is based on attracting and repelling properties of electromagnet [7]. The electromagnet can be operated by using both AC and DC supply but DC supply provides steady magnetic flux so the same is used in this work [8]. The electromagnetic engine can substitute as an alternative engine. It works completely on battery current, thus controlling the pollution to very large extent. It can be considered as a completely green technology and this is the need of current topic.

DESIGN OF ELECTROMAGNETIC ENGINE

This section includes design of parts that were assembled in an electromagnetic engine and designed as per specifications and requirement. Different parts like cylinder, electromagnet, piston etc. were designed in SOLID WORKS (R) modelling software to obtain better view of the parts.

Design of Piston Cylinder

The cylinder fit is one of the most important factors governing the success of a home-built model engine [9]. For electromagnetic engine it is better to avoid ferrous materials so that electromagnet is free to attract permanent magnet[10]. Because of this reason the iron cylinder is replaced by Aluminium cylinder. Isometric view of the specifications of the cylinder used in the present work is shown in Figure 1.

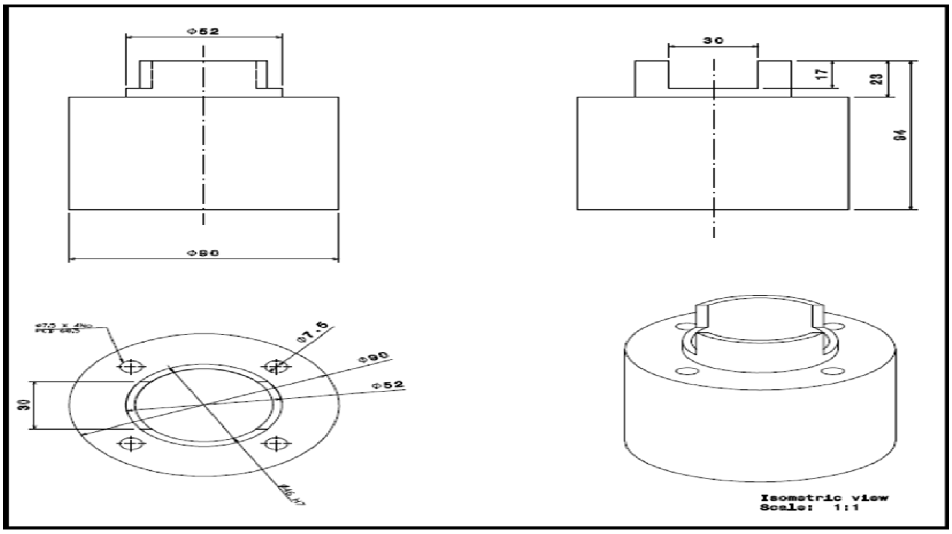

Figure 1: Isometric View of the Cylinder

Design of an Electromagnet

For the electromagnetic engine there are two different electromagnets, namely I bar electromagnet and Air core electromagnet. An electric current flowing in a wire creates a magnetic field around the wire and to concentrate the magnetic field, in an electromagnet the wire is wound into a coil with many turns of wire lying side by side. The magnetic field of all the turns of wire passes through the centre of the coil, creating a strong magnetic field there.

Calculations of Number of Turns of an Electromagnet

- An Electromagnetic engine is designed for power, P = 3.21 kW@1500 rpm
- The Power is related to Torque as, P= (2πNT)/60 kW

  Thus, T=Torque= (P×60)/ (2πN) N-m, T=20.48 N-m
- Force on the piston is calculated by using torque as,

  Crank efforts, F_r =T/r, where r=Crank radius = 0.03m

  F_r=20.48/0.03=682.71 N
- But Force on connecting rod, F_c= F_r/ [sin(θ+Ø)]

  Fc = 682.71/ (sin 60°)= 788.3 N
- Force on piston, F_p= F_c/cos (Ø)

  F_p=788.3/cos (20°) =844.71N
- But Force on Piston is also given by, $F_p = (B^2A)/(2\mu 0)$
- Thus Magnetic field required to move piston $B= \sqrt{(F_p \times (2\mu 0)/A)}$

  $B=\sqrt{844.71\times2\times4\pi *10^{-7}/2.123\times10^{-3}}$= 1 Tesla
- And the Magnetic field produced by an electromagnet is given by, B=μIn
- Turn density, $n=B/\mu I=1/(1.256\times10^{-3}\times 1)$=796.17 turns/m
- Hence, number of turns, N =n×L =796.17×0.2=160 turns

Specifications of an I-Bar Electromagnet

The specifications of the I-bar electromagnet used for the application is as tabulated in the Table 1. Schematic shown in Figure 2 depicts the design of the I-bar magnet used.

Table 1: Specifications of the I-Bar Magnet

Parameter	Dimension
Core material	Mild Steel
Wire used for winding	18 Gauge copper wire
Core diameter	20mm
Length of core	100mm
Number of turns in winding	160

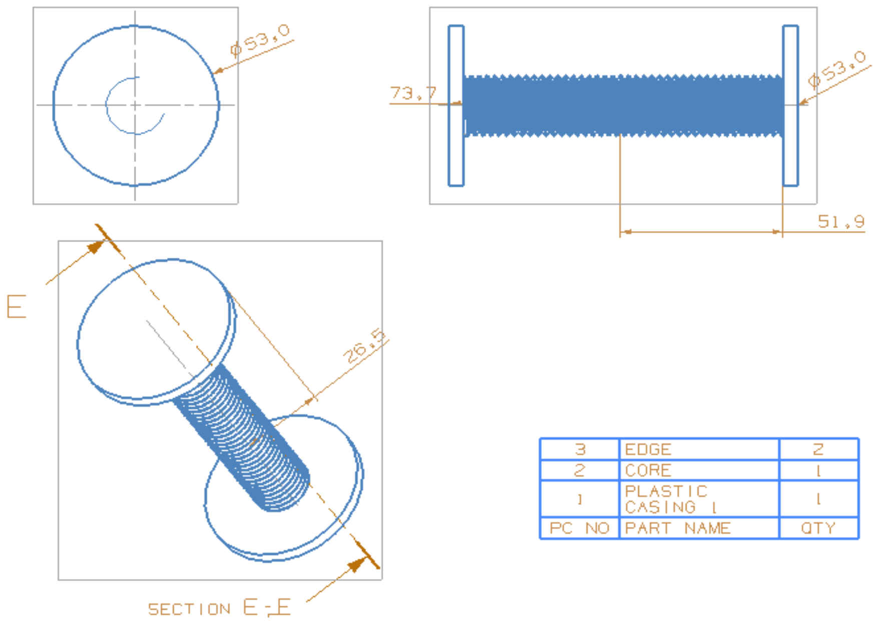

Figure 2: I-bar Magnet Used for the Electromagnetic Engine

Specifications of Air Core Magnet

The specifications of the air core magnet used for the magnetic engine is as mentioned in Table 2.

Table 2: Specifications of the Air Core Magnet

Parameter	Dimension
Core material	Air
Wire used for winding	28 Gauge copper wire
Core diameter	50mm
Length of core	5100mm
Number of turns in winding	5000

Design of Piston

Pistons are designed with features which perform specific functions during engine operation. Piston is made of cast aluminium because of its high heat transfer rate [11]. And for the electromagnetic engine it is very important to select non-ferrous material. The specifications of the pistons are as mentioned in the Table 3. Figure 3 represents the schematic of the piston.

Table 3: Specifications of the Piston

Parameter	Dimension
Piston material	Aluminium
Piston diameter	46mm
Piston length	50.4mm

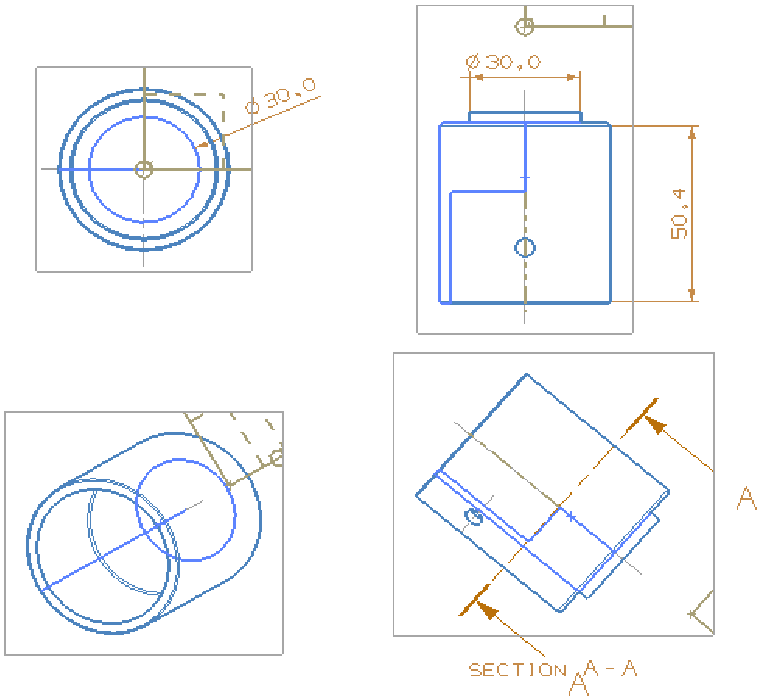

Figure 3: Piston Used in the Electromagnetic Engine

Design of Permanent Magnet

Neodymium magnets are the strongest type of permanent magnet commercially available. They have replaced other types of magnet in the many applications in modern products that require strong permanent magnets [12]. Neodymium magnet of diameter 25mm and thickness 5mm is used for the application in the present apparatus. Neodymium magnet used in the electromagnetic engine is as shown in Figure 4.

Figure 4: Neodymium Magnet Used in the Electromagnetic Engine

Design of Wire [13]

The wire is to be wound on the former (core) of the electromagnet. The following parameters are considered in determining the length. The diameter of the former is 10mm, the length of the pitch or former is 85mm and the diameter of the wire to be wound is 1.02mm.

The maximum number of winding in the first layer will be 100mm / 1.02mm =98.03 turns, chosen a stacking factor of 0.9, the maximum number of turns on the first layer will then be 98.03 × 0.9 = 88 turns.

If each layer is to have this maximum number of turns then, the total number of layers required to give the total number of turns will be, Total no of layers = total no of turns / no of turns on first layer =230 / 88 =2.7 layers = 3 layers.

When rewinding the wire, the perimeter of each subsequent layer will be increased by 2d, where d is the diameter of the wire i.e. (1.02mm)

First layer perimeter (length) will be $\pi D \times 88 = \pi \times 20mm \times 88$ turns = 62.84mm × 88 turns

Hence the length of one turn on first layer is 62.84mm

The length of one turn on second layer is 62.84mm + 2d = 31.42 mm + [2 × (1.02mm)]

The length of one turn on third layer = second layer perimeter + 2d

The AP formed has the following parameters:

- First term (a) = 62.84 mm, common difference d = 2d = (2.04mm), number of terms n = 3
- The length of the wire can be computed using sum of AP, Sum = n [2a+(n-1) d] / 2
- Substituting all parameters in above equation, sum = 194.64 mm
- Hence the total length required is the sum multiply by the total number of turns.

The total length is 194.64 x 88 = 17128.32 mm or 17.128 m

RESULTS AND DISCUSSIONS

This work makes use of electromagnetic principle the design and materials used for fabricating electromagnet are very important. Different types of electromagnet are to be tested for better lifting up of piston and efficient one should be chosen. Core materials for electromagnet also play important role in producing magnetic flux so different core materials are also to be tested. Therefore, different experiments are conducted in developing an electromagnetic engine and the magnetic flux produced by the electromagnet to give required force to the piston and power output produced by engine are calculated. The power is calculated twice as weight of the piston matters in an engine.

Calculation of Weight of Piston

- Length of the piston, l = 0.046m
- Diameter of piston, d = 0.052m
- Cross sectional area of the piston, $A = \pi d^2/4 = 2.123\times10^{-3}\ m^2$
- Length of the coil, L = 20 cm
- Number of turns, N = 160
- Turn density = (n) = N/L = 796.17 turns/m
- Current, I = 1 A
- Mass of the piston, m = Volume (V) × Density (ρ)

Volume = Area of the piston × Length = $9.76 \times 10^{-5}\ m^3$

Density of the piston, ρ =2700 kg/m^3

- Mass of the piston, m=2700×9.76×10^{-5} =0.2636 kg
- Weight of the piston, W =m × g = 0.2636 × 9.81 =2.586N

Calculation of Forces

- Force on the piston, F_p = (B^2A) / ($2\mu 0$)

  Fp= (1^2×2.123×10^{-3}) / (2×4π×10^{-7}) = 844.71 N

Force When the Piston Moves Downwards

- When the piston is moving downwards, force F_1= Fp +W

  F_1 = 844.71 + 2.586 = 847.296 N

- Force on connecting rod, F_{c1}= F_1 × cos(Ø)

  F_{c1} = 847.296 × cos (20°) = 796.19 N

- Crank efforts F_{r1}= F_{c1} × cos [90-(θ+Ø)]

  F_{r1}= F_{c1}×sin (θ+Ø)

  F_{r1} = 796.19 × sin (40°+20°) = 689.52 N

- Torque (T_1) = F_{r1} × r N-m, (where r = crank radius = 0.03 m)

  T_1 = 689.52× 0.03 = 20.68N-m

- Power (P_1) = ($2\pi NT_1$)/60 kW

  P_1 = (2π× 1500 × 20.67) / 60 = 3260.9 W at N= 1500 rpm.

Force When Piston Moves Upwards

- When the piston is moving upwards, force F_2= Fp – W

  F_2 = 844.71 - 2.586 = 842.124 N

- Force on connecting rod, F_{c2}= F_2 ×cos (Ø)

  F_{c2} = 842.124 × cos 20° = 791.35 N

- Crank efforts F_{r2} = F_{c2} × cos [90 - (θ+Ø)] N

  F_{r2}= F_{c2} × sin (θ+Ø) N

  Fr_2 = 791.35 × sin (40+20) = 685.33 N

- Torque (T_2) =F_{r2} × r N-m, (where r = crank radius = 0.03 m)

  T = 685.33 × 0.03 = 20.55 N-m

- Power (P_2) = ($2\pi NT_2$) / 60 kW

$P_2 = (2\pi \times 1500 \times 20.55) / 60 = 3227.99$ W at N= 1500 rpm

Discussions of Obtained Results

- The power of engine when piston moving downwards, $P_1 = 3260.9$ W at 1500 rpm.
- The power of engine when piston moving upwards, $P_2 = 3227.99$ W at 1500 rpm.
- The average power produced by the engine is,

  $P = (P_1 + P_2) / 2 = (3260.9 + 3227.99) / 2$

  $P = 3244.44$ W at 1500 rpm.

The Power of Engine can be Increased by:

- By increasing the more number of turns, the magnetic flux of the electromagnet will increase. Higher the magnetic flux of electromagnet, greater will be the repulsive and attractive forces between electromagnet and permanent magnet (piston). Due to this the crank will rotate at higher speed and it leads to engine with greater power.
- The power of engine can be increased by increasing the current. But there are some limitations with this. They are:
  - The iron core used in electromagnet get heated when we use higher current flow (at about 1.4 A) and it requires coolant i.e. water or liquid helium passing through it.
  - The copper used in electromagnet should be of higher quality so that it can withstand higher current (i.e 1.4 A).
  - The torque depends on the radius of the crank. Therefore, by increasing the radius of the crank we can increase the power of the engine.

Analysis of Power at Different Speeds

The power response of the engine based on the variation of the speed of operation of the engine is as tabulated in Table 4.

Table 4: Variation in Power Based on Operation Speed of Engine

Speed (rpm)	Torque (N-m)	Power (kW)
1500	20.48	3.24
3000	20.48	6.43
5000	20.48	10.72
7500	20.48	16.08

The variation of the engine power based on the speed of operation of the engine is also depicted in the plot as shown in Figure 5.

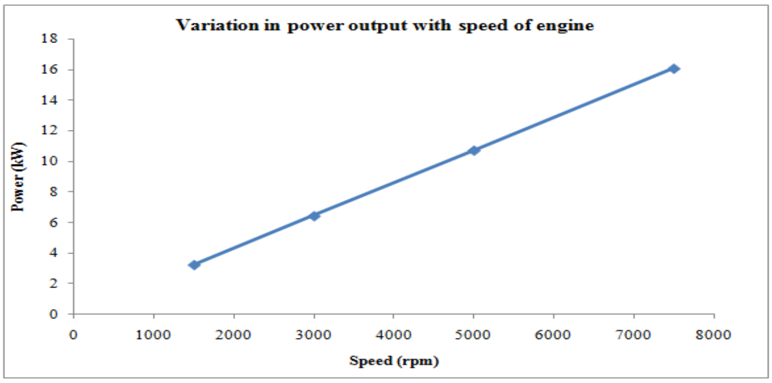

Figure 5: Plot of Variation of Engine Power with Engine Speed

Analysis of Power for Different Cores

In the graph of power vs speed, X-coordinate designates different values of speed of the crank and Y- coordinate designates corresponding values of power. The calculation is carried out for turn density n=500 turns/metre.

The graph of power vs speed shows that the power of engine is directly proportional to the speed of crank. Therefore, the power will increase as the speed increases and hence the plot is straight line. It can be observed that whenever the speed increases the power will increase but the torque remains constant. The power output obtained using various cores is as tabulated in Table 5 and the plot of power for various cores used is depicted in Figure 6.

Table 5: Power Generated by Engine Using Cores of Different Materials

Core Used	Permeability (Henry)	Magnetic Flux (Tesla)	Power (W)
Iron	1.256×10^{-3}	0.628	1277.561
Ceramic	2.136×10^{-3}	1.026	3004.621
Air	12.566×10^{-7}	0.0006	22.7823
Steel	0.942×10^{-3}	0.471	740.798

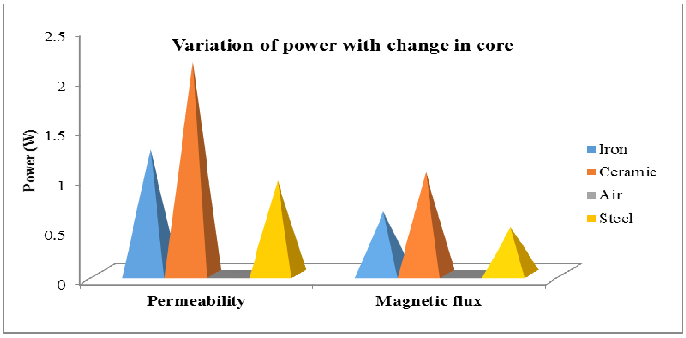

Figure 6: Variation in Power of Engine with Different Magnetic Cores

The permeability and magnetic flux is high for ceramic materials while for air core it is very low. The permeability of iron core is 1000 times that of the air so the magnetic flux is high as compared to air core. The magnetic flux is moderate for steel.

CONCLUSIONS

The present study aims to have substitute engine for conventional IC engine. The advantage of substitute engine is that no fuel is used and thus no pollutants are liberated by the burning of the fuel. The growing demand of fuel further

makes the attractive. The electromagnet based engine thus provides an attractive alternate option. This report presents, the details of the development of an electromagnet engine.

Based on the available design procedures the power output of the engine is calculated. The entire engine has been customized to meet the specifications mentioned. The I-bar electromagnet strength was practically found to be 0.23 Tesla.

The Winding wire (18 gauge) and turn density (800 turns/m) has been adopted in principle. The power source for the engine is supplied by DC current from lead acid battery.

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